Management of Tropical Forests 5

5.1 Introduction

People have managed tropical forests for extracting timber and other resources for millennia, but on a scale small enough not to damage the ability of the forest to recover its original structure and function. Today, many tropical forests of the world are being managed unsustainably, generally due to the intensity of the timber harvest and the lack of adequate techniques to preserve sustainability, that is, to preserve ecosystem structure and function and to ensure the ability of the forest to regenerate populations of desirable tree species. However, many management systems have been designed to avoid damage to the forest structure and to maintain the forest in production. In this chapter we examine management practices for long-term sustainability of natural forests, the way the practices have evolved, and current trends in forest management.

Systems for sustainable management of tropical forests should take into consideration features that are essential for the maintenance of the natural forests' structure and function:

- the maintenance of ecosystem biodiversity, including the mutualisms that are essential for forest reproduction;
- the maintenance of viable populations of wildlife;
- the maintenance of the nutrient retention and recycling mechanisms of the forest;
- the maintenance of soil organic matter.

5.2 Natural Forest Management

Natural forest management has been defined as "controlled and regulated harvesting, combined with silvicultural and protective measures, to sustain or

increase the commercial value of future stands, all relying on natural regeneration of native species" (Schmidt 1991). Compared to plantations and agroforestry, natural forest management systems are less intensive, with relatively lower short-term yields, but also requiring lower capital inputs. There is a long history of management of natural forests by indigenous peoples. For example, recent archaeological research in the Upper Xingú region of Brazil has revealed that a complex settlement pattern existed in the Amazon long before the arrival of European colonizers (years 1200–1600 a.d.). These settlements apparently greatly transformed the local landscape and sustained human populations without destroying biodiversity (Heckenberger et al. 2003; Stokstad 2003). Another recent study has shown a history of human occupation in other regions that otherwise were considered to be pristine, such as the Solomon Islands (Bayliss-Smith et al. 2003).

It appears that several cultures have been able to use the forest in a sustainable manner to their benefit. Even today, large areas of tropical forests are used by indigenous peoples. Such forests can be considered "human-dominated ecosystems", since many forests are actually used for gardening, agroforestry, hunting and gathering (Noble and Dirzo 1997). The key to using tropical forests to sustain human populations in indigenous societies has been to conserve the basic forest structure and function. Natural forest management of today is based on this same principle.

Modern natural forest management is often not sustainable, and has been criticized on a number of grounds (Buschbacher 1990; Bruenig 1996; Reid and Rice 1997; Pereira et al. 2002; Frederiksen and Putz 2003):

- It is based on a few valuable species including *Swietenia* spp. (mahogany) in Latin America, *Khaya* in Africa, and *Shorea* in Asia. Selective logging can reduce or extinguish local populations of these species.
- Other species are not used, because existing markets are often not sufficient to warrant their extraction.
- Selective logging practices cause a certain degree of damage to the forest, especially when felling and transportation of logs is carried out on steep slopes. Damage to the forest is highly dependent on the intensity of logging and therefore sustained forest management techniques necessarily restrict the amount of timber harvested.
- Due to the damage caused to the forest by selective logging, there is often not enough natural regeneration.
- Selective logging opens up areas that local people can use for shifting agriculture.
- Logging roads increase access to wildlife hunting.
- Opening of the canopy by logging increases risk of damage by fire.

In the following sections we explain how some of these negative effects can be avoided or counteracted, using knowledge of the basic ecology of natural forests to design sustainable management systems.

5.2.1 Sustainable Forest Management

According to the United Nations Environment Program (UNEP), sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs and does not imply in any way encroachment upon national sovereignty". It also implies "the maintenance, rational use, and enhancement of the natural resource base that underpins ecological resilience and economic growth". Sustainable development also implies incorporation of environmental concerns and considerations into developing planning and policies (UNEP Statement on Sustainable Development, Governing Council 1989, in Higman et al. 1999). Sustainable development is economically viable, environmentally benign, socially beneficial, and balances present and future needs (Higman et al 1999).

Sustainable forest management (SFM) is management of natural forests in such a way as to minimize the problems associated with timber extraction. SFM has been described as forestry's contribution to sustainable development. It aims at maintaining the productivity of the forest for timber and other human needs through preservation of soil fertility and hydrological stability. In addition, sustainable forest management maintains levels of biodiversity that occur naturally in the forest (Dawkins and Philip 1998). A more complete definition of SFM is given by Bruenig (1996):

> …management should aim at forest structures which keep the rainforest ecosystems as robust, elastic, versatile, adaptable, resistant, resilient and tolerant as possible; canopy openings should be kept within the limits of natural gap formation; stand and soil damage should be minimized; felling cycles must be sufficiently long and tree marking so designed that a selection forestry canopy structure and a self regulating stand table are maintained without, or with very little, silvicultural manipulation; the basic principle is to mimic nature as closely as possible to make profitable use of the natural ecosystem dynamics and adaptability, and reduce costs and risks….

Many SFM systems have been designed to follow these guidelines as closely as possible.

In the following section, we describe the principal systems of tropical forest management that have been or are still being used in different regions of the world. Then we focus on some recent initiatives that seek to standardize management techniques with the overall goal of increasing sustainability through the establishment of criteria and indicators of sustainable forest management, along with the development of "better management techniques" for forest management, such as reduced impact logging (RIL).

5.2.2 Systems Used in Management of Natural Forests in Tropical Regions

Some of the systems used to manage tropical forests worldwide are summarized in Table 5.1. Some of these systems are still practiced, while other systems have been discontinued or modified.

5.2.2.1 Natural Regeneration Systems

The success of management systems based on natural regeneration depends on the number of individuals of desirable species left after harvest. The species managed should be abundant, have a wide diameter distribution, and good quality timber. Diameter increments of managed species can be increased by selectively favoring desirable species through refinement and liberation treatments to reduce competition in the stand. Refinement and liberation are used in most systems of natural forest management. Refinement stimulates growth by eliminating the overstory of undesired species and individuals. It consists of the eradication of unwanted vegetation (weeds and defectives) to promote complete utilization of the site by high quality trees of the preferred species. Liberation is the freeing of desirable species from competitors by removing vines, lianas, and other plants that impede growth.

If wildlife conservation is a goal of natural forest management, care must be taken not to eliminate species that are a food source for wildlife. Also, defective trees are often habitat for certain birds like woodpeckers. Given the complex set of mutualisms that exist in tropical forests (described in Chap. 2), it would seem that too much refinement and liberation could "sterilize" the tropical forest by removing important food sources and habitat for

Table 5.1. Systems used in management of tropical forests worldwide

Type of method	Name of management system	Nomenclature	Country of origin or practice
Natural regeneration systems			
Monocyclic methods	Malayan Uniform System	MUS	Malaysia
Polycyclic methods	Celos Silvicultural System	CSS	Surinam
	Selective Management System	SMS	Throughout the world
Clearing systems			
Shelterbelt system	Tropical Shelterwood System	TSS	Nigeria, Ghana
Strip cutting system	Palcazu method		Peru

animals. Most natural regeneration systems lack consideration for faunal biodiversity (Bennett 2000). More recent approaches to SFM which include consideration of faunal biodiversity are discussed later in this chapter. Also, care must be taken not to destroy non-timber forest products (NTFPs) that are important for the subsistence of local populations.

Monocyclic Methods

The Malayan Uniform System (MUS) is one of the oldest and most widely known management system of natural forests in Southeast Asia. It was designed for forests that are relatively uniform and rich in commercial species of the *Shorea* genus in the Dipterocarpaceae family. The genesis and nature of the system have been described by Wyatt-Smith and Panton (1963). All trees of commercial size are harvested in a single operation, followed by poison-girdling of all unwanted stems (non-commercial species, or commercial species with defective stems). Three to five years after the initial harvest, diagnostic sampling is conducted to determine the status of regeneration and to prescribe treatments that will ensure good regeneration. Silvicultural treatments to promote regrowth include climber cutting (liberation) and poison girdling of unwanted trees competing with the more desirable species. These practices are applied at 10, 20, 40, and 60 years and the area is harvested again after 70 years.

In the MUS, regeneration was generally good on lowlands with fertile soils and the system was commonly used until the mid-1960s (Dawkins and Philip 1998). The low cost of mechanical extraction and making and maintaining roads and the lack of demand of other species created an ideal situation for the MUS in the lowland areas. However, competition with other land uses such as rubber and oil palm led to a displacement of this management system to more hilly terrain where conditions were not so favorable for natural regeneration (Buschbacher 1990). Another factor that contributed to the decline of the MUS was the increasing use of wood preservatives which permits the utilization of more species.

By the late 1980s, a selective management system (SMS), similar to one being used in the Philippines, was suggested as a more flexible and appropriate approach to suit the changing conditions of forest management in Malaysia. The new SMS required a pre-felling inventory where permanent sample plots are defined and used to determine growth rates by diameter classes and species groups, mortality, regeneration, and felling damage. The felling regime is then designed based on minimum diameter limits (MDL) for cutting that are defined for each species, so as to conserve the resource, ensure sustainability, reduce damage to the remaining forest, and optimize utilization. Yields of 30–40 m^3/ha were expected in 25- to 30-year cutting cycles, thus transforming the system into a polycyclic method. The system has yet to be

tested over time and success greatly depends on the efficacy of the control of logging (Dawkins and Philip 1998).

Polycyclic Methods

The Celos Silvicultural System (CSS), developed by the Wageningen Agricultural University of the Netherlands, has been proposed as a technically feasible balance of economic and ecological aspects of timber production in the seasonal evergreen forest of Surinam (De Graaf and Poels 1990). The CSS is a cost-effective way of growing more marketable wood in previously exploited neotropical rain forest, based on relatively short felling cycles of 20–30 years (De Graaf 2000). It can be used in natural or lightly used forest. The Celos system is designed for areas that are large enough to supply an economically viable timber processing unit. When the area under forest is abundant, an extensive system with low output per hectare is adequate.

The Celos system is based on the use of silvicultural operations in several cycles of interventions. For example, a harvest cycle may consist of an initial extraction of 10 m^3 with subsequent interventions after 8 and 16 years, with a target of a total of 20 m^3 of lumber/ha and a felling cycle of 20 years. Refinement and liberation are used as needed to stimulate the growth of desired individuals that are left as residuals.

The method is good for areas with relatively large tracts of forest thus permitting the extraction of fewer trees per hectare but resulting in a relatively high amount of total timber extracted. It should be noted that no complete set of treatments has yet been applied. The state of the forest after more than one rotation should be tested in the existing long-term plots where selective logging may be continued as intended under the CSS (Dekker and De Graaf 2003). Most management systems for natural tropical forests today are modifications of the SMS or the CSS geared to suit the local ecological characteristics of the forest as well as the economic conditions of the region (Box 5.1).

Box 5.1

Research on forest management systems at CATIE, Costa Rica

In Central America, long-term research at CATIE (Centro Agronómico Tropical de Investigación y Enseñanza, Tropical Agriculture Research and Higher Education Center) has focused on developing technologies for sustainable management of natural forests. Researchers have recently created models to predict and simulate growth and yields of natural forests and have generated quantitative and qualitative information on ecological and economic feasibility of natural forest management systems in the region (Montagnini et al. 2002).

A financial analysis of sustainable management in a harvested forest was recently conducted at the Tirimbina Rain Forest Research Center,

located in Costa Rica's Atlantic zone. The Tirimbina forest is part of a network of key sites for long-term research by CATIE on sustainable forest management in tropical America. Based on studies of economic feasibility and impacts on plant biodiversity of timber extraction, it was found that at least 30 ha with 10–15 m^3 of timber/ha should be harvested at each intervention if management is to be economically attractive and ecologically sustainable (Campos et al. 1998).

In these forests, post-harvest silvicultural treatments increased growth, especially for commercial species. Simulations using SIRENA, a growth and yield model (De Camino 1997), suggested that sustainable management can be achieved when harvesting is kept to moderate levels, when post-harvest treatments are applied to maintain an appropriate composition of commercial species, and when a cutting cycle of at least 20 years is used.

Other management systems in Latin America follow similar guidelines. It is still too early to know whether these systems are indeed both ecologically and economically sustainable. However, their chances are highly increased if they follow the criteria and indicators of sustainable management described in Section 5.4.1.

5.2.2.2 Partial Clearing Systems

Tropical Shelterwood System (TSS)

TSS was introduced in Nigeria and Ghana in the 1940s. In contrast to the MUS, the forests under management did not have enough regeneration potential, and therefore canopy openings were done several years prior to harvesting in order to promote adequate regeneration. Canopy opening by felling or poison-girdling selected trees was prescribed over a 5-year pre-harvest period. In practice, every tree not considered to have economic value was killed, resulting in severe canopy openings (65–80% of total basal area). This drastically increased light levels, leading to growth of vines and other light-demanding weeds instead of the desired regeneration of hardwood species. The system as practiced was not very effective. TSS could potentially work only in forests where light-demanding species are the desirable species and where climbers and weeds are not a big problem. In addition, the TSS is often too expensive for low-yielding forests (Dawkins and Philip 1998). The TSS was gradually abandoned in Ghana and Nigeria in the late 1970s and polycyclic methods were adopted. Variations of the TSS are sometimes utilized in tropical forests, generally as an initial treatment preceding other management operations.

Palcazu Method (Strip Cutting)

The Palcazu method, designed and applied in the Palcazu Valley of eastern Peru in the 1980s, was based on ecological observations of gap-phase dynamics of tropical forests. In natural forests, following gap formation, shade-intolerant species regenerate in the center of the gap, and more shade-tolerant species tend to occupy the borders. In the Palcazu method, the forest was cut in long narrow strips 30–40 m wide, simulating natural forest gaps to maximize utilization of the timber and to facilitate natural regeneration of trees. The strip clear-cuts were rotated through a production forest so that uncut primary forest or advanced secondary forest bordered a harvested strip. One strip was cut every year. Forest cutting was done using directional felling, cutting the trees so that they fell towards the already open area. Lianas were cut the year before felling. Extraction was done by oxen. A 40-year cycle was originally planned, to be done in parallel strips, leaving mature forest in between. Forest management using this strip cutting method was practiced on a total of 50,000 ha in an area with low hills. The project was based on an integrated use of products (sawn timber, poles, charcoal). There were two small sawmills on site to process the extracted timber. Initial evaluations of demonstration experiments using strip-cutting in the forest of the region were promising and showed that harvesting and extraction of wood could be done under the local conditions without serious environmental damage and that initial regeneration was rapid, abundant, and diverse (Hartshorn 1990).

The project was initially funded by the US Agency for International Development (USAID) to serve social objectives for communal lands of indigenous people living in the region, who were associated in a cooperative. The project suffered several difficulties after the withdrawal of the external financial and technical aid in 1989 due to the guerrilla activity in the region (Dawkins and Philip 1998). The cooperative continued the project for several more years but was faced with a variety of marketing and administrative difficulties. Costs exceeded revenues as timber prices were kept low under the national government policies at the time.

Yields were also lower than predicted by the pre-felling inventories. Silvicultural treatments were experimentally applied to the previously cut strips to test the effects on regeneration. Thinning significantly enhanced annual growth increments for stems in all regenerating categories of commercial species, with growth rates approximately twice those in the controls (Dolanc et al. 2003). However, economic sustainability of the system is still in question, as growth rates of commercial stems, even in thinned plots, were quite low (<0.3 cm/year for all categories).

5.3 Reduced Impact Logging (RIL)

Harvesting and extraction operations are the activities that generally cause the most significant impacts on the forest (Fig. 5.1). They include all the activities necessary to fell trees and remove them from the forest to the log site for loading and transport. Selective logging leads generally to a variety of short-lived and long-lived effects including changes in the light regime and forest micro-climate, erosion, soil compaction, disruption of nutrient cycling, and possibly long-term changes in tree species composition. These changes can affect the recruitment of timber species and the diversity of forest fauna. Selective logging also increases the forest's susceptibility to fire through modification of the understory micro-climate and supply of fuel (Pereira et al. 2002).

To make forest management systems more "environmentally friendly", silvicultural and management schemes have concentrated on decreasing forest damage by lowering the intensity of timber harvests and improving logging

Fig. 5.1. Manual extraction of sawn wood decreases forest damage in this communal forest of the Toncontín Agroforestry Group in La Ceiba, Honduras. The wood is sawn to boards of various sizes in a small frame sawmill in the forest. They transport the sawn wood 6 km average distance to the community, sometimes using also mules or horses. (Photo: CATIE)

practices (Bertault and Sist 1997; Sist et al. 1998). The quality of planning and the execution of harvesting and extraction are crucial in determining the state of the forest ecosystem following harvesting. The components of the reduced impact logging (RIL) approach can be adjusted to fit the specific forest conditions of each region or management unit, but they generally include (1) inventory and mapping to reduce waste during logging; (2) planning of roads, log decks, and skid trails to minimize ground disturbance; (3) vine or liana cutting 1 year prior to harvest to improve worker safety and eliminate damage to neighbors of harvested trees; (4) planned directional felling and bucking to minimize damage to future harvests and reduce waste; and (5) planned extraction to minimize equipment time during skidding. These practices may be complemented by silvicultural treatments to improve the long-term prospects for forest stand productivity.

RIL practices significantly limit damage compared to conventional logging practices, particularly at low or intermediate harvest intensities (Boxes 5.2 and 5.3).

Box 5.2

Impacts of RIL and conventional logging on forest damage in Indonesia

Sist et al. (1998) examined the impacts of conventional and reduced-impact logging (RIL) in East Kalimantan, Indonesia, by comparing pre- and post-harvest stand inventories. Felling provoked injuries in the remaining trees, mainly in their crowns. Skidding was the major source of tree mortality. RIL decreased skidding damage but failed to control felling damage. There was a positive correlation between logging intensity and the proportion of trees damaged by felling. If logging intensity was high (>8 trees/ha), the proportion of trees damaged in RIL was similar to conventional logging. They concluded that RIL techniques can reduce logging damage by 50% in comparison with conventional logging, if logging intensity were kept low or moderate (<8 trees/ha). The techniques used to extract trees should follow the specific restrictions of the RIL guidelines. For example, felling is not allowed in and around ecologically sensitive areas such as riparian strips or steep terrain. RIL also requires a higher rejection of trees by fellers when the felling direction is unpredictable. Results of more recent studies on the same forests led to new silvicultural rules to be used as part of RIL in these forests. These rules specify that it is necessary: to keep a minimum distance between tree stumps of about 40 m; to ensure only single-tree gaps; to use directional felling; and to harvest stems only in the 60- to 100-cm dbh range (Sist et al. 2003). The authors also suggest that RIL techniques should be expanded beyond silvicultural concepts, including the maintenance of other goods and services of the forest.

Box 5.3

Comparison of forest damage between RIL and conventional logging in the Amazon

In the eastern Amazon, the use of RIL resulted in about half to one-third the ground damage (roads + skid trails + log decks) when compared to conventional logging (CL). Canopy damage was also about half in RIL compared with CL treatments (Pereira et al. 2002). At this same site in Brazil, a comparison of costs and revenues for typical RIL and CL operations included estimations of productivity, harvest volume, wasted wood, and damage to the residual stand. The major conclusion of the study was that RIL was less costly and more profitable than CL under the conditions observed in the eastern Amazon site. The largest gain to RIL was provided by savings on the otherwise wasted wood. Large gains attributable to RIL technology were also observed in skidding and log deck efficiency. In addition, investment in RIL yielded an environmental dividend in terms of reduced damage to trees in the residual stand and reduction of the amount of ground area disturbed by heavy machinery (Holmes et al. 2002). The authors concluded that monetizing the value of the environmental dividend remains a major challenge in the promotion of sustainable forestry in the tropics.

RIL can also lead to economic savings. For example, in the Celos system in Surinam, the increased costs of planning with the use of RIL were found to pay off in increased efficiency (especially in skidding), reduced wastage, as well as reduced environmental damage. Savings in skidding costs with the use of RIL have also been reported in Sarawak (Higman et al. 1999). However, some studies have found higher costs in RIL than in conventional logging, due to the need for extra training, higher standings for road building, and higher costs of supervision. The fact that RIL is still of limited use throughout the tropics suggests that either it is more expensive or potential financial advantages are outweighed by other considerations (Leslie et al. 2002).

Logging impact alone is not always a good measure of the quality of forests that remain after logging (Wadsworth 1999). If better forest conservation is to result from low impact logging, it may require additional practices to those generally embodied in RIL. For example, directional felling could significantly reduce logging impacts if its purpose, in addition to ease of skidding, was also to avoid damage to immature trees. In sum, there is more to RIL than just guidelines on how to reduce logging damage. RIL should always be used in the broader context of sustainable forest management. RIL on its own may help reduce logging damage, but in isolation it will not ensure better forests.

A key aspect in sustainability of forest management is logging frequency. Logging intensity can be characterized by two aspects: static intensity (one-time logging) and dynamic intensity (frequency, i.e., cutting cycle). The regulation of frequency of timber removal (implementation of a cutting cycle) requires a management unit large enough to accommodate a reasonable cutting cycle, generally taken to be between 20 and 30 years, and at the same time large enough annual compartments so that the static harvest intensity can be kept reasonably low. As a result, sustainable management depends upon an adequate formulation of management units for which appropriate long-range management plans must be developed, specifying the manner in which logging intensity will be regulated, and the means by which productivity can be enhanced through silvicultural practices (Vincent 2002).

5.4 Ecological and Economic Feasibility of Methods of Management of Natural Tropical Forests

As seen from the description of the methods of management of tropical forests throughout the world, a variety of factors can affect their ecological, economic, and social feasibility. A key factor associated with the nature of tropical forests is the wide range of silvicultural characteristics of the desired species. Foresters need to have knowledge of the ecology and silviculture of several species in order to be able to design treatments that should be applied to suit the preferred species. For example, foresters need to know the light requirements for growth of the preferred species, so that they can apply the proper refinement and liberation techniques. There needs to be an adequate knowledge on tree species composition of the forest, both for performing pre-harvest inventories, as well as for evaluating the status of natural regeneration. Knowledge of the reproductive ecology of species is also needed; for example, if some of the harvested species are dioecious, care must be taken to ensure that other individuals of both sexes are present to ensure proper regeneration. Following initial treatments or canopy openings, additional silvicultural treatments (such as liberation and refinement) generally are needed to stimulate seedling regeneration in response to canopy opening and increased light availability.

Success of a management system lies in answering the following questions: are there enough seedlings, saplings, and advanced growth of merchantable species at time of exploitation to provide adequate stocking for the next harvest? What are the silvicultural characteristics of these species? What treatments will be necessary? What are probable growth rates and merchantable volume expectations of different species? What are the costs of the treatments? What is the cost of RIL?

In addition, in order for a management system to make sense from an economic point of view, an integrated land use policy is needed, where forest management is only part of the economic activities in a region. Forest management makes more sense economically when it is complemented by agriculture, tourism, or other activities. Socially, a successful forest management system has to provide safe employment to local people and suit their needs and preferences. For example, some successful forest management schemes are practiced by people who own forests in a communal system (explained in Chap. 7).

Given the wide variety of methods employed to manage natural forests in the tropics, efforts have been made to standardize the principles and criteria used to determine if a management system is ecologically, economically, and socially sustainable. A set of indicators has been defined to aid in the evaluation of the management systems suited to the particular conditions of each region, as explained in the next section.

5.4.1 Criteria and Indicators of Sustainable Forest Management

The International Tropical Timber Organization (ITTO) was created by treaty in 1983 with the objective of providing an effective framework for consultation among producer and consumer member countries on all aspects of the world tropical timber economy. ITTO brings together 56 member nations with interests in the trade of tropical timber and the management of tropical forests. The organization's task is to foster a tropical timber trade that simultaneously contributes to development in tropical countries and conserves the tropical forest resource on which the trade is based (www.itto.or.jp).

ITTO has pioneered the development of criteria and indicators (C & I) for the sustainable management of natural tropical forests. These are designed to assist tropical countries in assessing and reporting on compliance with forest management standards. A criterion describes a state or situation that should be met in order to comply with sustainable forest management. Seven criteria are identified as essential elements of sustainable forest management: criterion 1, *Enabling Conditions for Sustainable Forest Management*, is concerned with the general legal, economic, and institutional framework without which actions included under the other criteria could not succeed. Criteria 2 and 3 on *Forest Resource Security* and *Forest Ecosystem Health and Condition*, respectively, are concerned with the quantity, security, and quality of forest resources. The remaining four criteria deal with the various goods and services provided by the forest – *Flow of Forest Produce*, *Biological Diversity*, *Soil and Water*, and *Economic, Social, and Cultural Aspects*. The indicators have been carefully identified and formulated so that a change in any one of them

would give information that is both necessary and significant in assessing progress towards sustainable forest management. Wherever possible, quantitative indicators have been suggested, but, in some instances, this is impossible or prohibitively expensive. Where this is the case, qualitative or descriptive indicators are provided.

The purpose of ITTO's C & I is to provide member countries with an improved tool for assessing changes and trends in forest conditions and management systems at the national and forest management unit levels. These indicators identify the information needed to monitor change, both in the forest itself (outcome indicators) and in the environmental and forest management systems used (input and process indicators). The information generated using these C & I in assessing the state of the forest helps policy-makers to communicate their efforts towards sustainable forest management more effectively to the public. It can also assist in developing policies and strategies for sustainable forest management, in focusing research efforts where knowledge is still deficient, and in identifying those areas that are in special need of international assistance and cooperation.

The incorporation of ITTO's C & I in the national policies of many member countries is a major achievement, but implementing them at the forest level remains an enormous challenge (ITTO 2003a). Since ITTO undertook its pioneering work in the early 1990s, several international and regional initiatives on criteria and indicators for sustainable forest management have emerged, stemming from the UN Conference on Environment and Development held in Rio de Janeiro in June 1992. These initiatives involve more than 100 countries and include the Pan-European Helsinki Process, the Montreal Process for temperate and boreal forests, the Tarapoto Proposal for the Amazon, and regional initiatives for Dry-Zone Africa, the Near East, Central America, and the African Timber Organization (ITTO 2003b). In February 1997, the UN Commission on Sustainable Development's Intergovernmental Panel on Forests endorsed the concept of criteria and indicators for sustainable forest management and called on all countries to become involved in implementing them.

5.4.2 Certification of Forest Management

Forest management certification can be seen as a way to verify the quality of the management operations by an independent third party. Forest certification was set up as an instrument to transfer costs of sound forest management from forest owners to consumers. It can function as an economic incentive to producers and consumers that commit themselves to a more responsible use of natural forests (Upton and Bass 1996).

The Forest Stewardship Council (FSC) was founded in 1993 to promote good forest management by evaluating and accrediting certifiers by encourag-

ing the development of national and regional standards of forest management and strengthening national certification in developing countries. The FSC has declared ten principles and criteria; these are: (1) compliance with laws and FSC principles; (2) tenure use rights and responsibilities; (3) indigenous peoples' rights; (4) community relations and workers' rights; (5) benefits from the forest; (6) environmental impact; (7) management plan; (8) monitoring and assessment; (9) maintenance of high conservation value forests; and (10) plantations (Higman et al. 1999). Their principles and criteria direct attention to environmental, conservational, non-timber production, and social objectives, more than to the sustained production of timber; yet the certification scheme to provide consumers with reliable information about the source of forest products is centered on wood (Dawkins and Philip 1998). The FSC global principles and criteria are being adapted into regional and national standards worldwide in order to incorporate locally appropriate interpretations of performance standards. Once endorsed by the FSC Board, the local standards can be used by FSC-accredited certifiers when working in those regions (Higman et al. 1999).

However, certification of forest management does not necessarily guarantee sustainability. Rather, it provides effective and credible independent proof that the forest is being well managed, and presumably this will result in sustainability (Higman et al. 1999).

Although the cost of certification may not be expensive on a per hectare basis (Upton and Bass 1996), financing a certification scheme can be difficult when cash flows are precarious. An additional difficulty lies in finding staff with sufficient training to carry out certified forest management operations. If prices for certified wood do not compensate the cost of certification, there is little incentive to certify. However, there are non-financial benefits to certification. The certification process often serves as an interface between research, forest policy, and management. In Costa Rica and Guyana, for example, certification has served to link forestry research and policy. In these two countries, the process of choosing a certification scheme and developing a national certification standard and forestry policy was built upon existing research (Louman et al. 2002).

The C & I for sustainable forest management can also be used to define the criteria for certification of forest products. Certified products are more appealing to consumers concerned about the environment and often sell for better prices. In addition, some forest owners often pride themselves on practicing sustainable forest management and certification of forest products is a standard way to demonstrate sustainability.

5.4.3 Obstacles to Sustainable Forest Management

The idea that sustainable forest management can be an effective conservation tool rests, in part, on the premise that it can stabilize wood production in a given area. In principle, this would lead to conservation by maintaining forest cover and reducing pressures on other primary forests. However, this has rarely happened in practice (Bowles et al. 1998). There are steep hurdles facing broad adoption of investments in SFM. For one thing, such investments are almost always financially unattractive. Reaping a one-time harvest of ancient trees today is simply more profitable than managing for future harvests (Reid and Rice 1997).

Most countries with tropical forests do not have the capability to counter such financial incentives. Tropical countries are often feeding grounds for foreign logging corporations. Many developing countries have severe economic problems such as high inflation, unemployment, and foreign debt, and as a result are usually willing to attract investment (see Chap. 4). Many of these countries have weak environmental and social laws or little enforcement capabilities and are thus highly attractive to foreign loggers. Bribery and corruption can be severe problems because forest resources are often controlled by a few powerful individuals (Laurance 2000).

Just because there are serious obstacles to SFM does not mean that researchers and practitioners should give up the idea. The stakes are too great. Rather, it means that the effort to promote SFM must be redoubled and refined. There is already evidence that reduced impact logging, an important component of SFM, is economically attractive when looking toward the long-term profitability of the forested area. The problem arises when those with the authority over the resource have no responsibility for the future of that resource. Resolving the problem of exploitation of tropical forests means that *authority* over the land and the forest upon it must be more closely linked to the *responsibility* for the future of that resource.

5.5 Management of Secondary Forests

The term "primary forest" is used to designate a forest that has fully recovered formany past disturbance, and the structure and function resemble a forest that has never been cut. The term "secondary forest" is used for those forests that have recently regenerated following a natural (hurricanes, landslides) or human-induced (logging, clear-cutting, and replacement by agriculture or other land use) disturbance. Secondary forests in the tropics occupy larger and larger areas as the area of primary forest decreases and agricultur-

al areas are abandoned due to unsustainable practices. For example, in Central America, secondary forests are rapidly growing on abandoned pasture lands (Kaimowitz 1996).

The area of secondary forests has been estimated to increase at a rate of about 1 million ha/year (Achard et al. 2002). The type and rate of formation of secondary forests varies from region to region. There are two broad categories of secondary forest. One is residual forest that has been cut over once or more in the past 60–80 years. Because they have never been completely felled, they retain some of their former characteristics. The other type, called fallow or "volunteer", is forest that has regrown after being clear-cut for agriculture, pasture, timber extraction, or some other use. Because volunteer forests are composed largely of pioneer species, they lack both the structure and the composition of a mature forest. About 55% of secondary forests in the tropics as a whole are cutover forests and 45% are fallow (volunteer) (Wadsworth 1997).

Most secondary forests that developed after selective timber extraction are located in tropical Asia (47%), followed by tropical America (32%) and tropical Africa (21%) (Brown and Lugo 1990). The structure and composition of these secondary forests vary according to forest age, site fertility, previous land use, and distance from seed sources. The economic potential of each secondary forest for management for timber has to be determined with inventories that take into consideration the marketability of possible products. In general, secondary forests that originated from abandoned agricultural lands are closer to centers of human population, and therefore access and markets are not a problem. Most of the species growing as volunteers are heliophilous (light-demanding) and therefore likely to respond positively to silvicultural treatments such as thinning and liberation. A potential disadvantage of secondary forests as timber sources is the relatively lower market value of the timber species present, especially in comparison with primary forests. However, the markets change as the supply of more valuable timbers diminishes. Many secondary forests are good sources of fuelwood, non-timber forest products, pulp, and timber for local use.

In addition, tropical farmers have long depended on secondary forest fallows to restore productivity to land worn out by cultivation. When a secondary forest replaces a crop or pasture, the production of biomass by the vegetation and the cooler soil temperatures under the forest canopy contribute to the addition of organic matter to the soil. Typically, in most tropical humid areas, fallow periods of 5–15 years are required for soils to recover organic matter so that soils can be farmed again (Van Wambecke 1992). The type of secondary vegetation and the species composition influence the rate of recovery of soil fertility and the specific nutrient inputs to the soil. Farmers often enrich the fallow with fruit trees or other useful species, thus making use of the fallow and sometimes even accelerating the recovery of soil fertility.

5.5.1 Techniques for Management of Secondary Forests

The techniques used in management of secondary forests are generally similar to those used in management of primary forests, consisting of some type of selective management, generally followed by silvicultural treatments. Forest enrichment techniques are also often used as a way to increase the biological and economic value of secondary forests (Montagnini et al. 1997). Forest enrichment techniques are discussed in Chapter 6.

In refining secondary tropical forests, foresters select crop trees according to their prospective marketability, present size relative to maturity, form, freedom from injuries, and apparent health. If there is advanced regeneration of shade-tolerant, late-successional species (preferred crop trees) and the canopy is dominated by light-demanding mid-successional species, the only way to successfully regenerate another secondary stand is to remove all commercial volume at once in a monocyclic system (Guariguata 2000). In contrast, if a stand has plenty of shade-tolerant poles of good commercial value, a polycyclic system may be possible. Finegan (1992) suggested rotations of 15–25 years for neotropical secondary forests with light-demanding commercial species, depending on species composition and production goals. Silvicultural treatments should be applied when a closed canopy of longer-lived species has been formed. Under a monocyclic system, treatments will focus on liberating light-demanding crop trees from competition in the canopy, while under a polycyclic system, both light-demanding canopy species and advanced regeneration of shade-tolerant species are considered for liberation (Kammesheidt 2002; Box 5.4).

Table 5.2. Annual median diameter increment (in cm) of crop trees of the species studied, 2 years after thinning in a young secondary forest in the Caribbean lowlands of Costa Rica. (Data from Guariguata 1999)

Species	Control	Thinned
Laetia procera	0.4	1.0
Tapirira guianensis	0.5	1.4
Simarouba amara	1.7	1.8
Vochysia ferruginea	0.7	1.8
All species	0.7	1.2

Fig. 5.2. A *Cecropia* tree in a secondary forest on the Pacific coast of Costa Rica (note a sloth hanging from a branch near the center). Several species of *Cecropia* are characteristic of early stages of succession in secondary forests in Latin America. (Photo: F. Montagnini)

Box 5.4

Research on management of secondary forests by CATIE

Despite the large body of ecological information on secondary forest succession in Central America, few forestry-based experiments have investigated how secondary forests react to management practices. CATIE researchers are characterizing secondary forest structures and floristics and developing guidelines for sustainable management in Costa Rica and Nicaragua (Current et al. 1998; Guariguata 1999). In Costa Rica, the area of secondary forests already exceeds the area of primary forest legally available for production, while in Puerto Rico nearly all forest cover is classified as secondary forest (Kammesheidt 2002; Fig. 5.2).

In Costa Rica, CATIE has investigated the effects of silvicultural practices such as liberation thinning, whole-canopy removal, and substrate

preparation techniques on stand dynamics and regeneration of secondary forests in order to provide guidelines for sustainable management of timber. In the Atlantic lowlands of Costa Rica, short-term growth responses in individuals of four commercial species (*Laetia procera*, *Simarouba amara*, *Tapirira guianensis*, and *Vochysia ferruginea*) were evaluated following liberation thinning in a young secondary forest. Liberation thinning significantly increased the diameter growth of future crop trees with respect to unmanipulated counterparts (Table 5.2). The study concluded that young stands in the region may be attractive systems for simple silvicultural manipulations due to rapid growth responsiveness, facilitated by manageable tree size (Guariguata 1999).

The type of intervention needed for management will significantly vary according to the status of secondary forests. In tropical Asia, five major categories can be found: post-extraction secondary forests, post-fire secondary forests, swidden fallow secondary forests, secondary forest gardens, and rehabilitated secondary forests (Chokkalingam et al. 2001). An understanding of where each particular forest is situated in a continuum of disturbances and regeneration stages can help guide management of secondary forests.

5.6 Management for Non-Timber Forest Products (NTFPs)

As seen in Chapter 1, tropical forests provide a wealth of plant and animal products and a variety of environmental services. Management of forest resources must be viewed in the context of the surrounding land and natural resources. Likewise, management for timber cannot be completely separated from management for NTFPs. In fact, timber extraction often affects populations of NTFPs, including plants and animals.

Designing systems for diversified forest management involves studies on the ecology and management of non-timber species, including trees, herbs, and palms used locally or regionally for medicine, insecticides, ornamental purposes, craftwork, and construction (Fig. 5.3). Sustainable management for the use of these resources is based on studies on the capacity of each species to supply the desired products in a sustainable manner. Silvicultural guidelines for management are developed for each species. Development of silvicultural systems that include sustainable management plans for NTFPs requires knowledge of the biology and uses of the species, including the population structure and estimated amount of harvestable product.

In many cases, traditional extraction may lead to the exhaustion of the NTFP resource (Marmillod et al. 1998). For example, Brazil nuts (*Bertholletia*

Fig. 5.3. Palms are important non-timber forest products that are extracted from forests for a variety of uses. Some species of *Chamaedorea* palm, known as xate, are extracted from forests in Guatemala and other countries of Central America to export to the USA for ornamental uses. (Photo: F. Montagnini)

excelsa) are a classic NTFP and are the only internationally traded seed crop collected exclusively from natural forests (Fig. 5.4). A recent analysis of 23 populations of the Brazil nut tree across the Brazilian, Peruvian, and Bolivian Amazon has shown that populations subjected to high levels of harvest lacked juvenile trees; only populations with a light history of exploitation contained large numbers of juvenile trees (Peres et al. 2003). Without proper management, intensively harvested populations may succumb to a process of senescence and demographic collapse, threatening this cornerstone of the Amazonian extractive economy. Another example is the ornamental plant *Zamia skinneri* in Central America, whose excessive extraction is leading to very low populations in natural forests (Box 5.5).

Fig. 5.4. A Brazil nut tree (*Bertholletia excelsa*) in the delta of the Amazon River in Pará, Brazil. (Photo: F. Montagnini)

Box 5.5

The extraction of *Zamia skinneri* from Central American forests led to its inclusion in Appendix II of CITES

Zamia skinneri, a 2.5-m palm-like cycad (Cycadaceae family), is currently included in Appendix II of CITES (Convention on International Trade in Endangered Species) (Robles et al. 1997; Maiocco 1998). Only commercial exports of seeds are allowed for species included in Appendix II. *Zamia skinneri* used to be extracted from natural forests throughout all its natural range in Costa Rica, Nicaragua, and Panama to be sold as an ornamental plant, in both national and international markets. Several species of *Zamia* grow naturally from the southern USA to Bolivia. The Central American species of *Zamia* live in the understory of tropical humid forests. *Zamia skinneri* grows in an altitudinal range from 20–1,100 m. It only grows in

forests and cannot be grown in open plantations because it cannot tolerate direct exposure to the sun. *Zamia skinneri* is an ancient species, often considered a living fossil. In the Dominican Republic, archaeological records show that *Zamia* spp. was used by indigenous tribes about 1400 years b.c. The Banwari people of the Dominican Republic used to cook and eat the stems of this plant, in a manner that is similar to the use of cassava or manioc roots. Its value as food contributed to the protection of the forests in which it grows (Maiocco 1998). In present times interest in *Zamia skinneri* has grown because of its use as an ornamental. Much of the demand comes from the US. Due to its endangered status and high commercial value, researchers at CATIE have been studying its ecological requirements in order to design more sustainable manners of extraction from natural forests or cultivation in the appropriate environment (Robles et al. 1997; Maiocco 1998; Marmillod et al. 1998).

Extraction of NTFPs is not a priori more sustainable than timber extraction. On the contrary, NTFPs are equally threatened by overexploitation and abuse. In addition, changes in the social structure or living conditions of local people may lead to abandonment of NTFP extraction. In most cases, NTFP extraction is carried out by relatively poor sectors of the population. If their economic conditions change they may choose other less laborious and more profitable activities (Bruenig 1996).

Market forces also tend to impede sustainable management of NTFPs. Once an NTFP enters the cash economy, the usual cycle – establishing a market, rising demand, more intensive harvesting, collapse of the price, and finally substitution – tends to develop (Dawkins and Philip 1998). As demand increases there is a trend away from wild collecting and towards commercial domestication and cultivation. For example, wild-collected rubber from the Amazon could not compete with rubber from plantations of rubber trees in Asia. Even in such poverty-stricken regions as Amazonia, the long-term trend of social and economic evolution towards improved living conditions may make the collection of NTFP in natural rainforests less attractive.

Management for NTFPs can only be viable in the context of other land uses and economic activities for human populations. For example, there are reported cases where communities have organized themselves to crop communal land, extract timber, manage the forests for NTFPs, and reserve some forest areas for ecotourism (Montagnini et al. 2002).

5.7 Is Forest Management Compatible with Conservation of Biodiversity?

Many tropical forests have been subject to low-intensity human management for centuries: this management generally preserves environmental functions and species diversity (Gómez-Pompa 1991). Because of increased awareness of the importance of sustainability and the preservation of biodiversity, many tropical countries have recently changed forest management regulations to make them compatible with the principles of sustained yield and biodiversity preservation (Boyle and Sayer 1995). The ITTO and Forest Stewardship Council principles, criteria, and indicators for SFM give special emphasis to conservation of biodiversity. Specific guidelines are needed to cover the vast array of forest conditions that are present in each situation: species, soils, environmental constraints, markets, and other factors. The management guidelines should be adjusted to suit the scale and objectives of management in each particular case. In addition, methods are needed to evaluate ecological indicators that can serve to verify effects of management on long-term forest productivity and maintenance of biodiversity (Lowe 1995).

Operational definitions of diversity are required to provide practical and consistent frameworks for measuring and monitoring biodiversity. Typically, four different levels of diversity have been considered for measuring and monitoring biodiversity: genetic, species, ecosystems, and landscape levels (Boyle and Sayer 1995). Species diversity is conceptually the simplest of the four levels of organization of biodiversity, both because many species are visually distinct and because species extinction is an emotionally dramatic event. Practical measures of biodiversity tend to focus on the species level. Studies of genetic diversity have been done for several tree species of commercial value, and in some cases they have led to regulations about species conservation (e.g., a ban on logging mahoganies in Costa Rica; Navarro et al. 2002).

There are many published studies of the effects of forest management on biodiversity. For example in a forest reserve in Misiones, Argentina, a "Uniform Spacing" (US) method of forest harvest was used, where trees were selected for extraction or marked for retention according to scarcity, horizontal distribution, and quality as seed trees (Fig. 5.5). The system is called Uniform Spacing because the trees remaining after its application tend to be uniformly spaced. Generally the cutting intensity in the US method is about half that of conventional logging methods. In this case, no silvicultural treatments were applied following timber harvest. Forest regeneration following timber harvest was compared between the US method and conventional logging methods to see the effects of the different harvest techniques on forest biodiversity. Three years after harvesting, the forest cut by uniform spacing had the highest total density of seedlings for commercial and non-commercial species, and also exhibited

Fig. 5.5. *Ocotea puberula* trees are generally extracted from forests in Misiones, Argentina, due to their high timber value. However, in the Guaraní Forest Reserve, when cutting was done using the Uniform Spacing method, this individual was left standing, while a nearby tree of the same species was cut (note remaining stump in *foreground*). (Photo: F. Montagnini)

higher diversity of understory plants compared with forest cut using conventional logging methods (Montagnini et al. 1998). In the US system the resulting forest had higher variability of microenvironments which led to the establishment of a greater variety of species. In contrast, in the conventional cutting method the intensity or extraction was higher, resulting in greater canopy openings, which led to the establishment of more bamboo, ferns, and grasses. Other studies in Costa Rica also report on changes in forest composition following post-harvest silvicultural treatments (Box 5.6).

Box 5.6

Changes in species composition following silvicultural treatment in Costa Rica

In Costa Rica, results of a silvicultural experiment carried out by CATIE in a primary forest focused on the effects of logging and post-harvest silvicultural treatments on forest species richness and composition during the first 6–7 years following logging and 5 years following the application of silvicultural treatments (liberation and refinement) (Montagnini et al. 2001). The forest studied exhibited marked compositional variation in relation to a topographical gradient after the implementation of the experiment; such β- or "ecosystem diversity" should be taken into account in evaluations of the effect of forest management on plant biodiversity. In this forest, post-harvest silvicultural treatments caused an immediate reduction in species richness in individuals greater than 10 cm dbh. This was due to the chance elimination of species represented by one or a small number of individuals in the plots. It was concluded that post-harvest silvicultural treatments may affect overall species composition by favoring commercial species. However, no changes of species richness or composition were evident in the forest understory (individuals between 2.5–9.9 cm dbh). The direct felling and extraction of timber caused the only detectable changes in understory plant biodiversity and these changes were found only in the localized areas disturbed by these management operations.

Another study in Latin America reports that conventional low-intensity mahogany harvesting in lowland Bolivia has only a relatively mild physical effect on the forest. However, it is doubtful if this would hold true for the much more intensive harvesting characteristics of the eastern Amazon or the dipterocarp forests of Southeast Asia (Pearce et al. 2003).

In the forests of Central Africa, Hall et al. (2003) compared forest structure and tree species composition between unlogged forest and forests that had been subjected to highly selective logging 6 months and 18 years prior to the study. While there was little difference in tree species composition and diversity between treatments, stem densities were significantly higher in the unlogged forests than those in the forest sampled after 18 years since logging. In the logged forest there was insufficient recruitment of the principal timber species *Entandrophragma* spp. (African mahogany). However, many other quality timber species remained after selective logging, making logging still attractive long after elimination of the preferred species.

Some species function as indicator species, meaning that their presence is indicative of high biodiversity and a well-functioning ecosystem (Lindenmayer et al. 2000). Such ecosystem functions can include stand structural complexity, plant species composition, connectivity, and heterogeneity. Carefully designed studies are needed to test the relationships between the pres-

ence and abundance of potential indicator species and the maintenance of ecosystem processes in forests.

In conclusion, SFM techniques can contribute to maintaining biodiversity in tropical forests managed for timber production. Application of silvicultural treatments following harvest may immediately reduce species richness by eliminating species represented by few individuals. The effects of forest management operations on plant biodiversity depend on the nature of the operation. Studies are clearly needed to assess the long-term effects of forest management on plant and animal biodiversity. Any systems designed to restore degraded ecosystems should be focused on recovering at least part of the lost biodiversity (Montagnini 2001).

5.7.1 Effects of Forest Management on Wildlife

Wildlife is affected by logging in many ways. The direct effects of timber extraction on wildlife depend on the intensity and frequency of logging and the species involved. Some species, such as certain insectivorous birds, can disappear completely after a single intervention (Bennett 2000). Many species such as primates and hornbills decline in numbers, whereas populations of other species such as browsing ungulates can increase due to the rapid growth of browse as the canopy is opened. Secondary effects of logging can also include increases in hunting due to the opening of roads and increases in human populations depending on bush meat as a protein source.

Particularly important to the long-term survival of the forest are any impacts that logging can have on some of the mutualisms that may exist between plants and animals. Forest animals may act as seed dispersers, and if their populations are altered due to logging or increased human intrusion, the reproduction and survival of tree species may be endangered. An exam-

Table 5.3. Number of sightings of mammalian fauna at the study sites in the Caribbean lowlands of Costa Rica over a 6-month period (Guariguata et al. 2000)

Species	Tirimbina No. (no./ha)	La Selva No. (no./ha)
Alouatta palliata (howler monkey)	4 (0.06)	8 (0.13)
Ateles geoffroyi (spider monkey)	2 (0.03)	15 (0.24)
Cebus capuchinus (white-faced monkey)	7 (0.10)	7 (0.11)
Dasyprocta punctata (agouti)	–	2 (0.03)
Puma concolor (puma)	–	2 (0.03)
Tamandua mexicana (tamandua)	–	2 (0.03)
Tayassu tajacu (collared peccary)	–	4 (0.07)
Sciurus variegatoides (squirrel)	1 (0.01)	2 (0.03)
Total	14 (0.19)	32 (0.52)

ple showing the loss of fauna from managed forests and some consequences for long-term forest survival is given in Box 5.7.

Box 5.7

Effects of logging on loss of fauna from Costa Rican forests

Many studies have examined the effects of selective logging on animal populations. In Costa Rica, the effects of faunal loss on the dispersal, predation, and survival of seeds and seedlings were recently studied in two selectively logged forests with differing levels of protection (Guariguata et al. 2000). La Selva Biological Station, owned and operated by the Organization for Tropical Studies (OTS), is protected from hunting and connected to a national park, whereas the Tirimbina forest is unprotected and not connected to a park. Seed dispersal rates by mammals were highest in the protected site. Seed survival was also higher at La Selva. The low rate of seed dispersal and survival at Tirimbina is probably related to altered mammal community composition as a result of hunting pressure and loss of habitat connectivity (Table 5.3).

Even if forests are logged with minimal stand and soil disturbance, sustained recruitment of mammal-dispersed timber species appears less likely if loss of habitat connectivity and excessive hunting pressure are combined. Production forests adjacent to parks and conservation areas may be more likely to maintain a wider spectrum of viable populations of plants and animals than forests in which logging is permitted throughout.

As seen in Section 5.4.1, ITTO standards also include biodiversity, although there is no specific mention of management practices that consider faunal diversity. Likewise, conservation of wildlife is not specifically included in the Forest Stewardship Council Principles and Criteria for SFM. The concept of eco-agriculture, or managing for diversity as well as for production (McNeely and Scherr 2003), could be extended to forestry with the term eco-forestry, meaning managing forests for biodiversity as well as for production. In such cases, consideration should be taken of the total biodiversity of the forest, including wildlife. This may lead to increases in the costs of managing and monitoring, but may be essential for the long-term survival of forest ecosystem functions.

5.8 Reserves

Deforestation, whatever its causes and motivation, is the most powerful direct threat to forest biodiversity. Some support the view that the conservation of biodiversity requires halting deforestation and keeping commercial timber production out of forests (Leslie et al. 2002). This is the principle underlying

the creation of totally protected areas (TPAs). However, few countries are willing or able to place all of their natural forests in TPAs. Most countries, under present economic conditions, have no choice but to continue encouraging the harvesting of timber growing in their natural forests.

Other opinions hold that biodiversity can also be conserved in production forests under sustainable management regimes; total conservation should be the first strategy and SFM is only preferred in cases when the alternative land use is wholesale logging or dramatic land use change; in some cases it is better to allow one-time conventional logging, followed by complete protection of the area (Reid and Rice 1997). However, this seems to be quite impractical given that there is no guarantee that the logged area can be effectively protected. In addition, regeneration following conventional logging may be good in some types of forests but not in all types (McRae 1997).

In order to maximize the diversity of species that are conserved, it is essential to address biodiversity conservation at the landscape level. Some species require large areas to conserve a viable population. The question of scale is important when considering the impacts of disturbance on forest biodiversity and when designing strategies for biodiversity conservation. There are different measures of biodiversity on different scales. For tropical forests greater than 10^6 km^2 in size of Africa, Asia, and the Americas, overall or "gamma diversity" (or diversity found across large geographical regions) varies from perhaps 30,000–120,000 species of flowering plants. Smaller forest plots ranging from 0.001–0.01 km^2 in area contain from 30–300 tree species ("alpha" or "within-habitat diversity"). Less information is available on "beta" or "between habitat diversity", which describes how species composition varies from one area to another. How diversity varies among plots of similar sizes in different forests and with distance among plots is a question relevant to the design of protected areas. For example, Condit et al. (2002) found that regions in Panama and the western Amazon that are 10^4 km^2 in area support 3,500–5,000 tree and shrub species, yet at smaller scales (0.01 km^2), the western Amazon forests support two to ten times as many species as do Panamanian forests. This raises the question, is it more worthwhile to preserve an Amazon forest than a Panamanian forest of similar size? Numbers may not be the only factor that matter when considering the preservation of species; the answer may depend on which species are present – their rarity, scarcity, and value (known and potential but unknown) to humans.

There are difficult issues relating to the size and spatial arrangement of protected and managed areas. The general conclusion is that protected areas should be as large as possible, but that ultimately their value as refuges depends more on their integrity and optimal distribution across the landscape than on their absolute size (Boyle and Sayer 1995). Several studies have shown that forest fragment sizes and degree of isolation are the prime determinants of species loss (Boyle and Sayer 1995). For example, Laurance et al.

(1997) reported that rain forest fragments in central Amazonia experienced a dramatic loss of above-ground tree biomass that was not offset by recruitment of new trees. These losses were largest within 100 m of fragment edges, where tree mortality was sharply increased by microclimatic changes and elevated wind turbulence. Permanent study plots within 100 m of edges had lost up to 30% of their biomass in the first 10–17 years after fragmentation. Habitat fragmentation affects the ecology of tropical rain forests by altering the diversity and composition of fragment biotas and changing ecological processes like nutrient cycling and pollination (Laurance et al. 1997). Therefore a strong case can be made for the maintenance of corridors of undisturbed forest linking refuge areas.

The conservation of species in isolated fragments of TPAs will be enhanced if these areas are surrounded by areas of modified, but biologically diverse, buffer zones, transition zones, and corridors (Boyle and Sayer 1995). ITTO's Guidelines for the Conservation of Biological Diversity in Tropical Production Forests suggest that there will be some degree of biodiversity loss in tropical production forests that would be mitigated by a comprehensive and integrated TPA network. The function of production forests in biodiversity conservation would be to allow the persistence of a large portion of the original biodiversity within a buffer zone around the TPAs, and to provide corridors that allow the free flow of genetic material among the forested areas (Leslie et al. 2002).

Some innovative plans, such as the UNESCO Man and the Biosphere (MAB) program's worldwide network of biosphere reserves, have begun considering the needs of local people by incorporating biophysical and socioeconomic factors into the management plans of protected areas (Khasa and Dancik 1997). A typical UNESCO MAB Reserve includes a core area under complete protection surrounded by buffer zones where a variety of human activities are possible. These include SFM, agroforestry, ecotourism, and even human settlements in the outer limits of the buffer zones. Similarly, extractive reserves, in which local people are responsible for forest management, have been developed for timber products in Quintana Roo, Mexico, and for NTFP extraction (mainly rubber and Brazil nuts) in Brazil.

5.8.1 Setting Priorities

The number of species threatened with extinction far outstrips available conservation resources; therefore at some point priorities must be set. Biodiversity "hotspots" have been defined as places in the world where there are high concentrations of endemic species that are undergoing exceptional loss of habitat (Myers et al. 2000). As many as 44% of all species of vascular plants

and 35% of all species of four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth. Should we concentrate our efforts on protecting these "hotspots?" This is an example of how knowledge of the distribution of biodiversity can be used in designing an effective strategy for conservation and management. The hotspots strategy does not exclude other areas from urgent conservation in accord with alternative criteria. For example, patterns of speciation should also be considered when determining conservation priorities (Myers 2003). There is a large degree of overlap between the biodiversity hotspots and other internationally recognized initiatives for conservation, such as the IUCN/WWF International Centers of Plant Diversity and Endemism and the endangered eco-regions of the WWF/US Global 200 List. The hotspots thesis has the potential to reduce the mass extinction under way by about one-third and has been considered as the most important contribution to conservation in the last century (Myers 2003).

5.9 Conclusion

Systems for sustainable management of tropical forests take into consideration those aspects of tropical forest ecology that are essential for the future existence of the forest:

- biodiversity, not only for the intangible benefits of biodiversity, but also because the diverse mutualisms that depend upon the survival of each species are essential for forest reproduction;
- nutrient retention and recycling mechanisms of the forest, especially the organic material on top of soils or near their surface.

The solution to maintaining diversity and associated mutualisms, maintaining nutrient cycling, and maintaining soil organic matter so essential to all functions of tropical ecosystems may lie not in any one management measure, but rather in a whole suite of measures, which will vary from country to country and situation to situation (Vanclay 1992). Furthermore, management to sustain the forest resource cannot be based upon ecological factors alone, but also must take into consideration social, political, economic, and cultural factors. These factors will be discussed in Chapter 7.